BASIN MARGIN MESAVERDE OIL

USGS 2210

The Basin Margin Mesaverde Oil Play is a con firmed oil play around the margins of the central San Juan Basin. Except for the Red Mesa field on the Four Corners platform, field sizes are very small. The play depends on intertonguing of porous marine sandstone at the base of the Upper Cretaceous Point Lookout Sandstone with the organic-rich Upper Mancos Shale.

Reservoirs: Porous and permeable marine sandstone beds of the basal Point Lookout Sandstone provide the principal reservoirs. The thickness of this interval and of the beds themselves may be controlled to some ex tent by underlying structures oriented in a northwest erly direction.

Source rocks: The upper Mancos Shale intertongues with the basal Point Lookout Sandstone and has been positively correlated with oil produced from this inter val (Ross, 1980). API gravity of Mesaverde oil ranges from 37 degrees to 50 degrees.

Timing: Around the margin of the San Juan Basin the upper Mancos Shale entered the thermal zone of oil generation during the Oligocene.

Traps: Structural or combination traps account for most of the oil production from the Mesaverde. Seals are typically provided by marine shale, but paludal sediments or even coal of the Menefee Formation may also act as the seal.

Exploration status and resource potential: The first oil-producing area in the State of New Mexico, the Seven Lakes Field was discovered by accident in 1911 when a well being drilled for water. It produced oil from the Menefee Formation at a depth of approxi mately 350 ft. The only significant Mesaverde oil field, Red Mesa, was discovered in 1924. Future dis coveries are likely to be small.

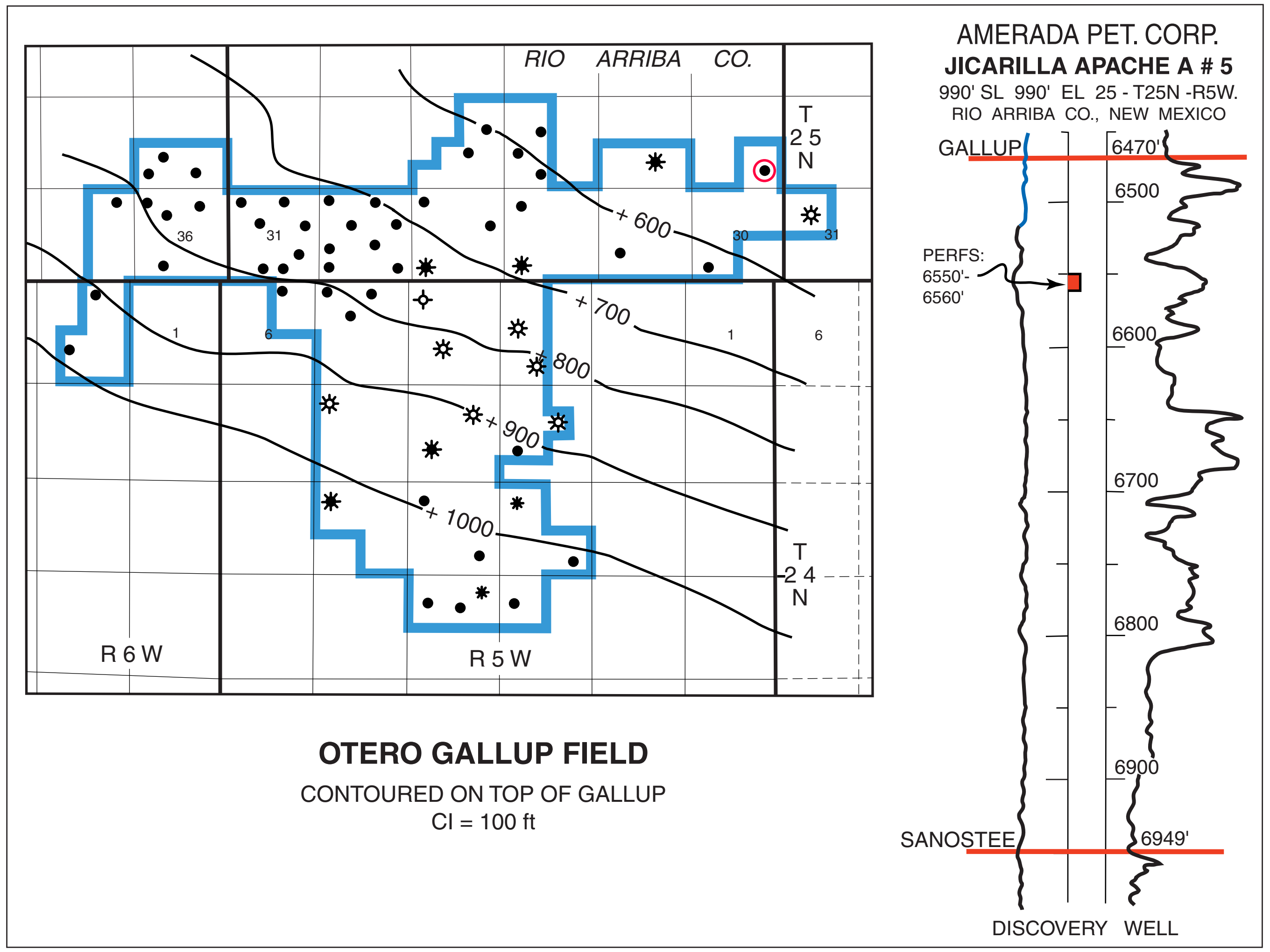


Figure J-20. Otero Gallup Field structure map and example electric log (from Brown, 1978, p. 444).

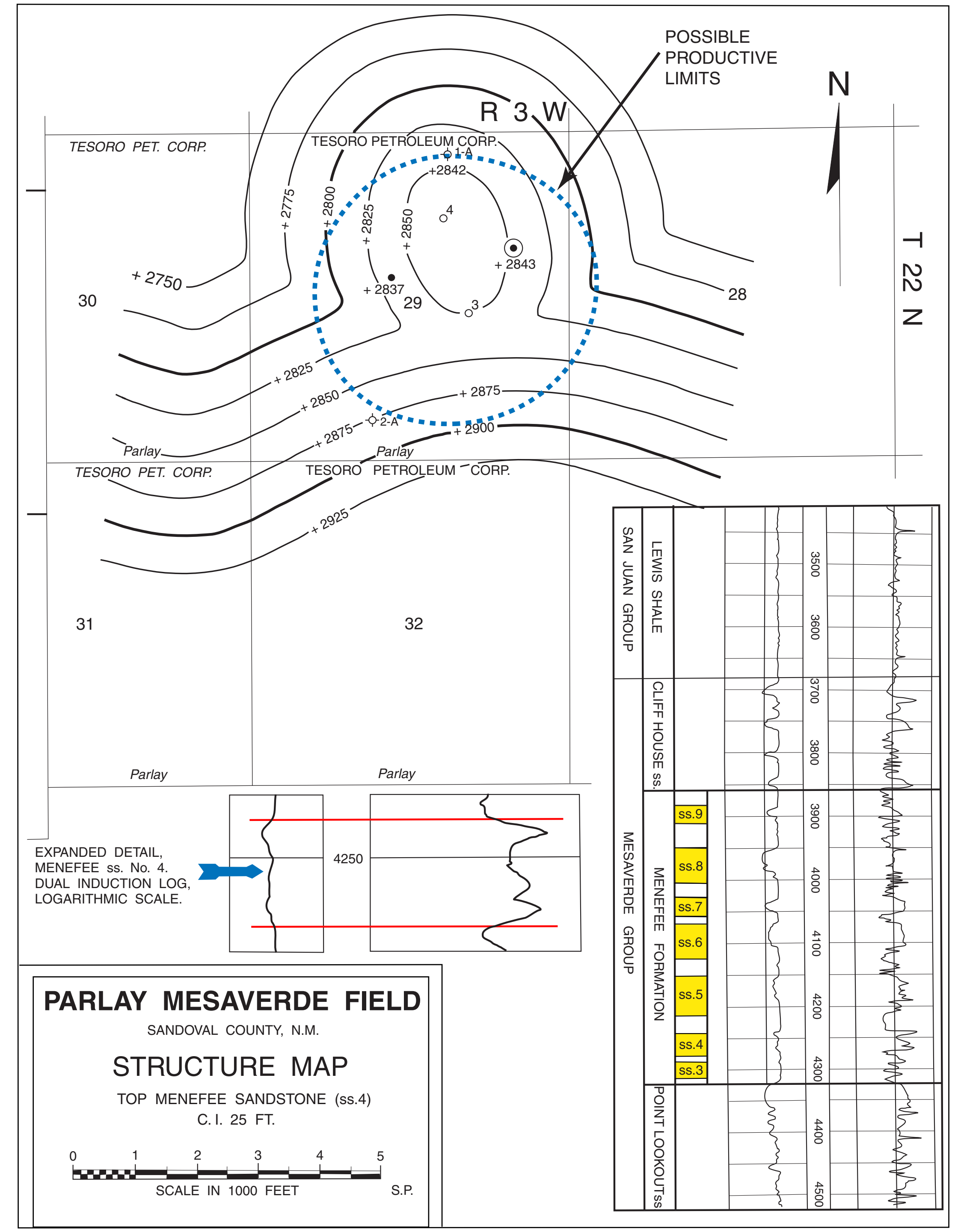


Figure J-21. Parlay Mesaverde Field, structure map and example electric log (after Gray, 1978, p. 453).

Analog Field: PARLAY MESAVERDE

Figure J-21

Location:	T22N, R3W, on Reservation
Formation:	Mesaverde, Point Lookout member
Lithology:	Sandstone
Average Depth:	4,250 feet
Porosity:	19%
Permeability:	6.45 mD
Oil/Gas Column:	30 feet
Average Net Pay Thickness:	15 feet
Other Information:	Oil gravity is 44.2 degrees API, high paraffin. Estimated ultimate recovery is 18% of OOIP or 121,200 BO for the field. Associated gas yields 1,279 Btu with no sulfur.

Analog Field: OTERO GALLUP

Figure J-20

Location:	T24-25N, R4-6W, on Reservation
Formation:	Gallup
Lithology:	Sandstone
Average Depth:	6500 feet
Porosity:	6%, fracture enhanced
Permeability:	Unknown
Oil/Gas Column:	10 feet per bench
Average Net Pay Thickness:	8 feet one bench, 14 feet two benches
Other Information:	Oil is 40.7 degrees API. Reservoir has gas drive.

FRUITLAND-KIRTLAND FLUVIAL SANDSTONE GAS PLAY

USGS 2212

On the Jicarilla Apache Indian Reservation, the uppermost Cretaceous Fruitland Formation produces coal gas methane. West of the Reservation, the gas source is the associated Kirtland shale. This discussion is included here because of the possibility of finding conventional Fruitland gas accumulations on the far west side of the Reservation. Please see the discussion on Pictured Cliffs coal gas, USGS Play 2211, in the Unconventional Play section that follows.

The Fruitland-Kirtland Fluvial Sandstone Gas Play covers the central part of the basin and is characterized by gas production from stratigraphic traps in lenticular fluvial sandstone bodies enclosed in shale source rocks and (or) coal. Production of coalbed methane from the lower part of the Fruitland has been known since the 1950's. The Upper Cretaceous Fruitland Formation and Kirtland Shale are continental deposits and have a maximum combined thickness of more than 2,000 ft. The Fruitland is composed of interbedded sandstone, siltstone, shale, carbonaceous shale, and coal. Sandstone is primarily in northerly trending channel deposits in the lower part of the unit. The lower part of the overlying Kirtland Shale is predominantly siltstone and shale, and differs from the upper Fruitland mainly in its lack of carbonaceous shale and coal. The upper two-thirds or more of the Farmington Sandstone Member of the Kirtland Shale is composed of interbedded sandstone lenses and shale.

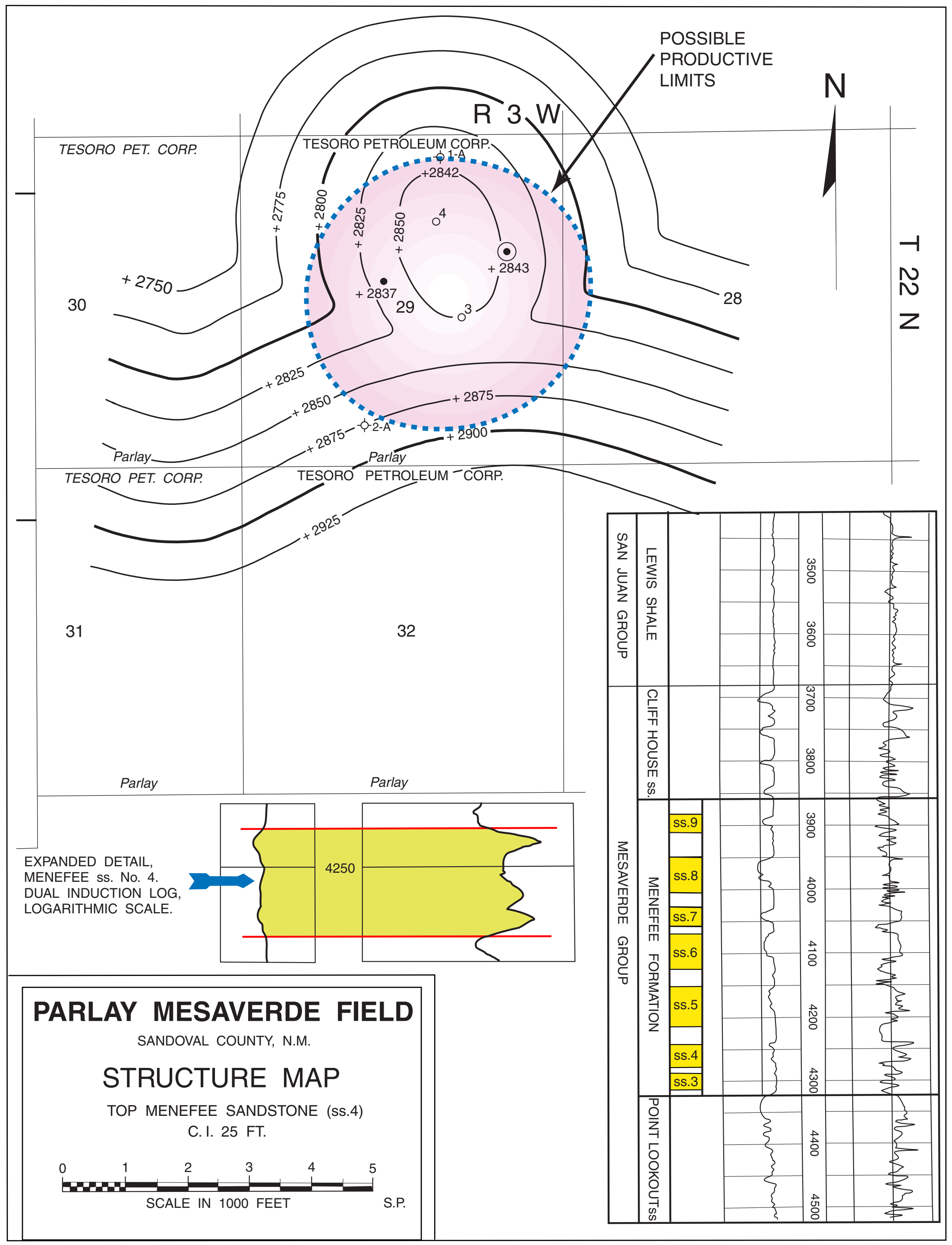


Figure J-21. Parlay Mesaverde Field, structure map and example electric log (after Gray, 1978, p. 453).

Reservoirs: Reservoirs are predominantly lenticular fluvial channel sandstone bodies, most of which are considered tight gas sandstones. They are commonly cemented with calcite and have an average porosity of 10 -18 percent and low permeability (0.1 - 1.0 millidarcy). Pay thickness ranges from 15 to 50 ft. The Farmington Sandstone Member is typically fine grained and has porosity of from 3 to 20 percent and permeability of from 0.6 to 9 millidarcies. Pay thicknesses are generally 10 to 20 ft.

Source rocks: The Fruitland-Kirtland interval produces non-associated gas and very little condensate. Its chemical composition (C1/C1-5) ranges from 0.99 to 0.87 and its isotopic (d13C1) compositions range from -43.5 to -38.5 per mil (Rice. 1983). Source rocks are thought to be primarily organic-rich non-marine shales encasing sandstone bodies.

Timing and migration: In the northern part of the basin, the Fruitland Formation and Kirtland Shale entered the thermal zone of oil generation during the latest Eocene and the zone of wet gas generation probably during the Oligocene. Migration of hydrocarbons updip through fluvial channel sandstone is suggested by gas production from immature reservoirs and by the areal distribution of production from the Fruitland.

Traps: The discontinuous lenticular channel sandstone bodies that form the reservoirs in both the Fruitland Formation and Kirtland Shale intertongue with overbank mudstone and shale and paludal coals and carbonaceous shale in the lower part of the Fruitland. Although some producing fields are on structures, the actual traps are predominantly stratigraphic and are at updip pinchouts of sandstone into the fine-grained sediments that form the seals. Most production is from depths of 1,500-2,700 ft. Production from the Farmington Sandstone Member is from depths of 1,100-2,300 ft.

Exploration status and resource potential: The first commercially produced gas in New Mexico was discovered in 1921 in the Farmington Sandstone Member at a depth of 900 ft in what later became part of the Aztec field. Areal field sizes range from 160 to 32,000 acres, and almost 50 percent of the fields are 1,000-3,000 acres in size. The almost linear northeasterly alignment of fields along the western side of the basin suggests a paleofluvial channel system of northeasterly flowing streams. Similar channel systems may be present in other parts of the basin and are likely to contain similar amounts of hydrocarbons. Future potential for gas is good, and undiscovered fields will probably be in the 25 sq mi size range at depths between 1,000 and 3,000 ft. Because most of the large structures have probably been tested, future gas resources probably will be found in updip stratigraphic pinchout traps of channel sandstone into coal or shale in traps of moderate size.

ANALOG FIELD: **Los Pinos Fruitland, South**

Figure J-22

Location:	T31N, R7W, west of Reservation
Formation:	Fruitland
Lithology:	Sandstone
Average Depth:	3,000 feet
Porosity:	11.9%
Permeability:	0.96 md
Oil/Gas Column:	200 feet
Average Net Pay Thickness:	41 feet
Other Information:	Gas yields 980 Btu per CF and contains about 4% carbon dioxide and nitrogen. Estimated ultimate recovery is 2.5 BCFG per well.

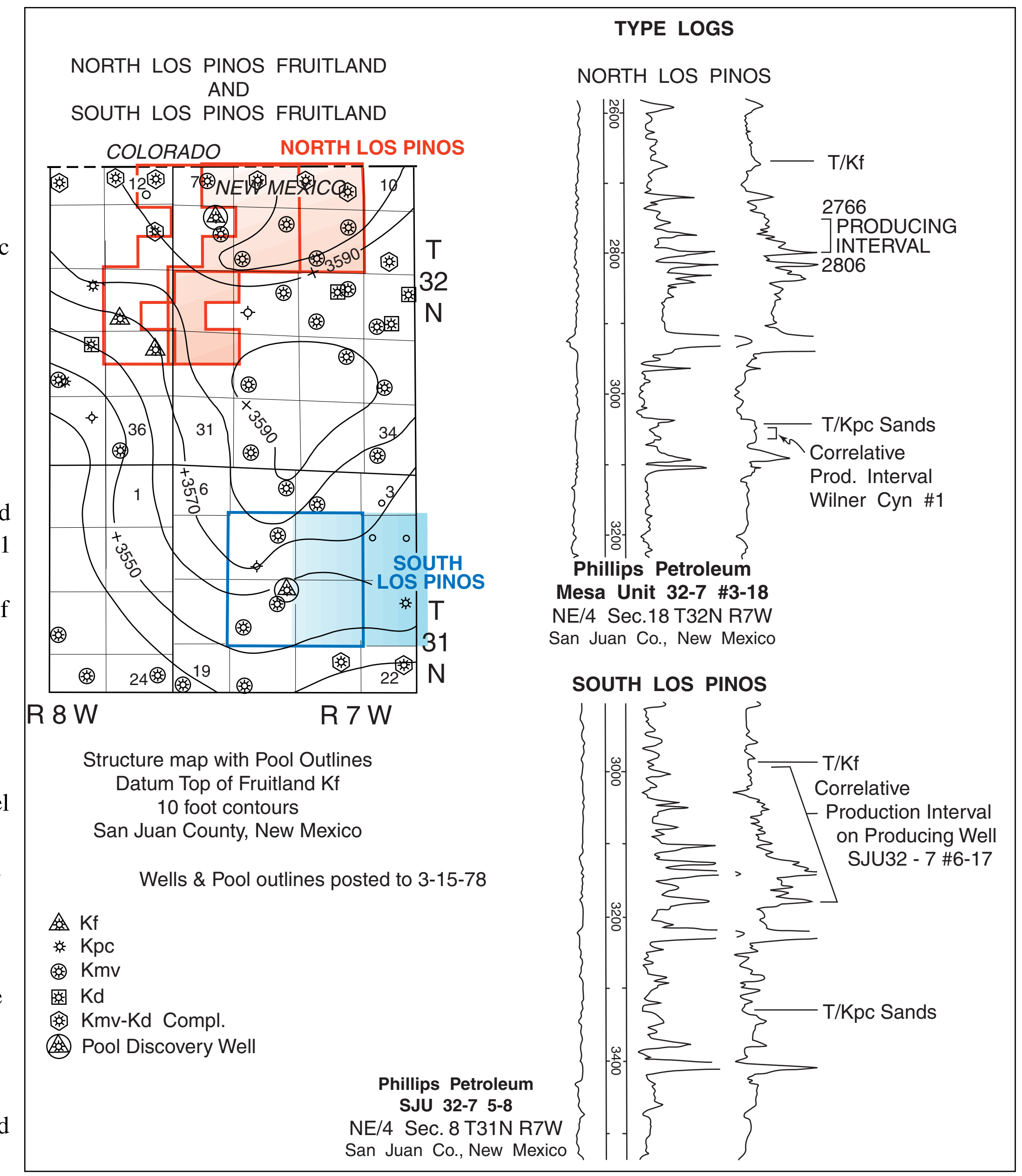


Figure J-22. Los Pinos Fruitland South Field, structure map and example electric logs (from Bowman, 1978, p. 393).

Unconventional Plays -- Definition

A broad class of hydrocarbon deposits of a type (such as gas in "tight" sandstones, gas shales, and coal-bed gas) that historically has not been produced using traditional development practices. Such accumulations include most continuous-type deposits.

DAKOTA CENTRAL BASIN GAS PLAY

USGS 2205

The Jicarilla Apache Indian Reservation is on the east flank of the San Juan Basin but extends sufficiently westward that there is a possibility of finding unconventional Dakota formation gas reservoirs. The preceding discussion on the conventional Basin Margin Dakota Play, USGS Play 2206, characterizes existing Reservation Dakota production on the Reservation.

The Dakota Central Basin unconventional continuous-type play is contained in coastal marine barrier-bar sandstone and continental fluvial sandstone units, primarily within the transgressive Dakota Sandstone.

Reservoirs: Reservoir quality is highly variable. Most of the marine sandstone reservoirs within the Basin field are considered tight, in that porosities range from 5 to 15 percent and permeabilities from 0.1 to 0.25 millidarcies. Fracturing, both natural and induced, is essential for effective field development.

Source rocks: Quality of source beds for oil and gas is also variable. Non-associated gas in the Dakota pool of the Basin field was generated during late mature and postmature stages and probably had a marine Mancos Shale source (Rice, 1983).

Timing and migration: In the northern part of the central San Juan Basin, the Dakota Sandstone and Mancos Shale entered the oil generation window in the Eocene and were elevated to temperatures appropriate for the generation of dry gas by the late Oligocene. Along the southern margin of the central basin, the Dakota and lower Mancos entered the thermal zone of oil generation during the late Miocene (Huffman, 1987). It is not known at what point hydrodynamic forces reached sufficient strength to act as a trapping mechanism, but early Miocene time is likely for the establishment of the present-day uplift and erosion pattern throughout most of the basin. Migration of oil in the Dakota was still taking place in the late Miocene, or even more recently, in the southern part of the San Juan Basin.

Traps: The Dakota gas accumulation in the Basin field is on the flanks and bottom of a large depression and is not localized by structural trapping. The fluid transmissibility characteristics of Dakota sandstones are generally consistent from the central basin to the outcrop. Hydrodynamic forces, acting in a basinward direction, have been suggested as the trapping mechanism, but these forces are still poorly understood. The seal is commonly provided by either marine shale or paludal carbonaceous shale and coal. Production is primarily at depths ranging from 6,500 to 7,500 ft.

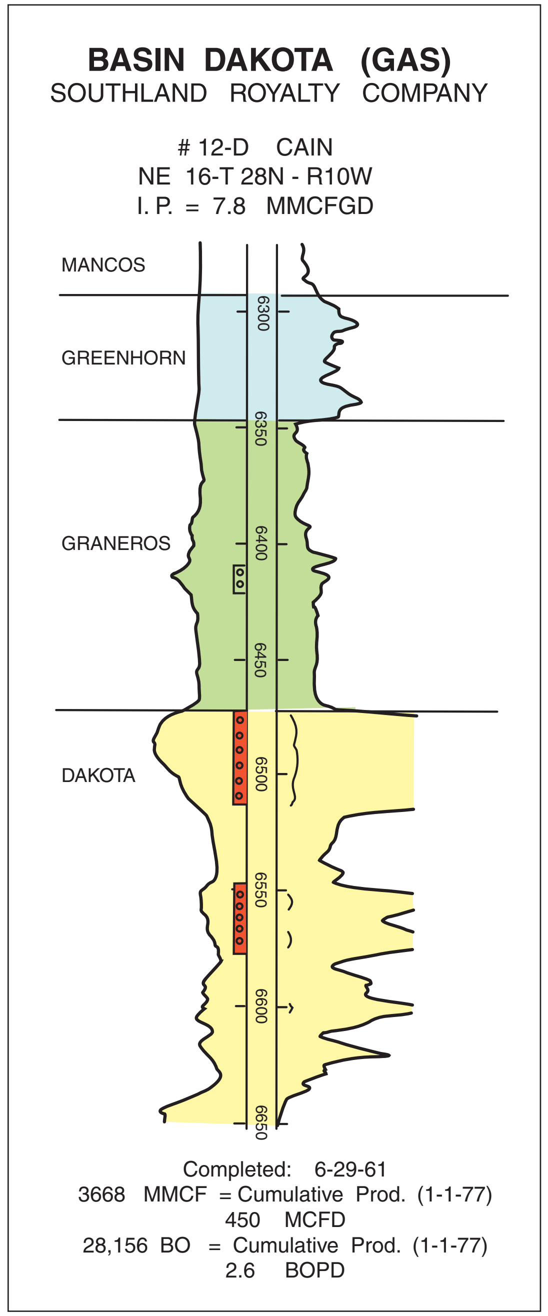


Figure J-23. Basin Dakota Field, example electric log (after Hoppe, 1978, p. 205).

Exploration status and resource potential: The Dakota discovery well in the central basin was drilled in 1947 southeast of Farmington, New Mexico, and the Basin field, containing the Dakota gas pool, was formed February 1, 1961 by combining several existing fields. By the end of 1993 it had produced over 4.0 TCFG and 38 MMB condensate. Almost all of the Dakota interval in the central part of the basin is saturated with gas, and additional future gas discoveries within the Basin field and around its margins are probable.

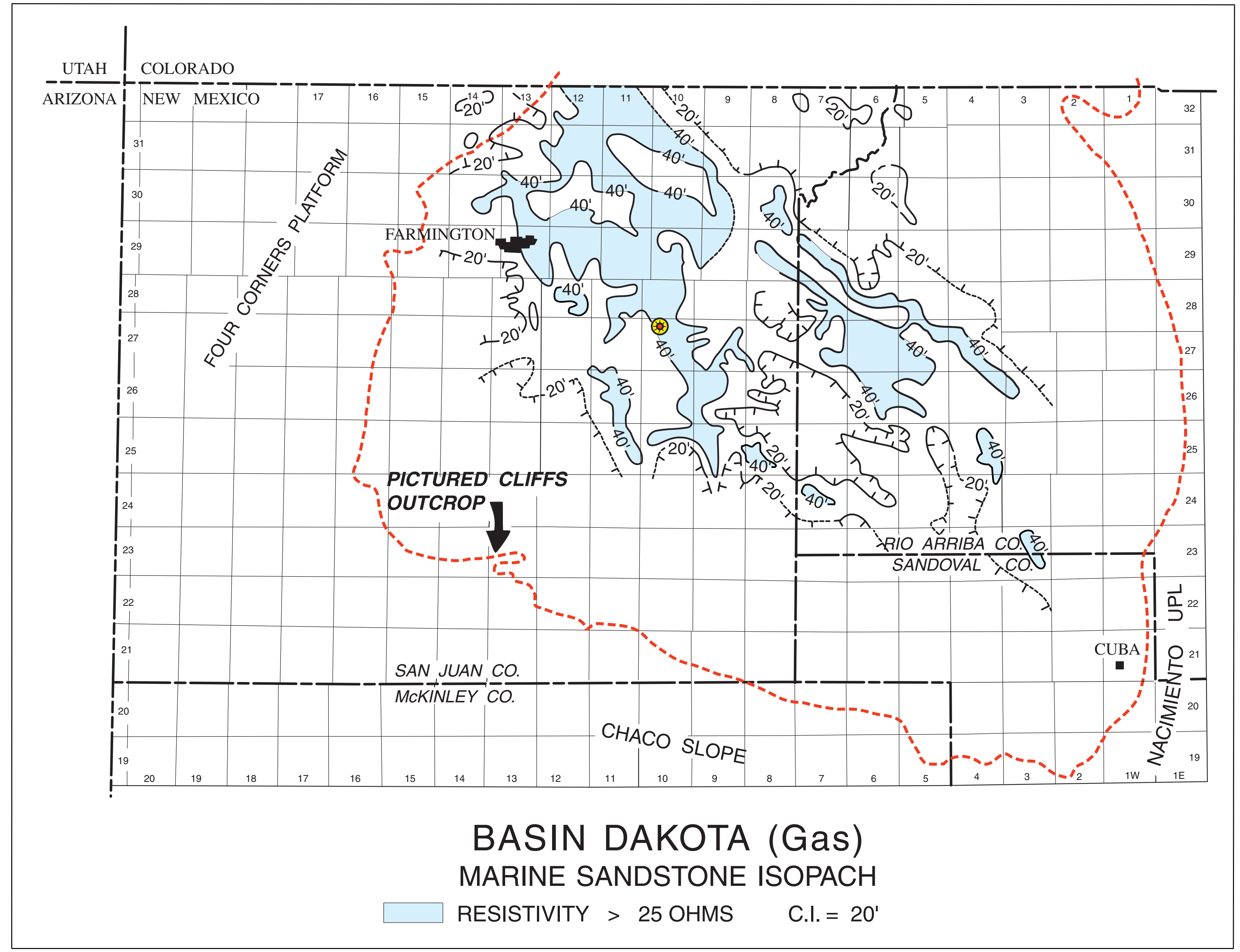


Figure J-24. Basin Dakota Field, area and marine sandstone isopach map (from Hoppe, 1978, p. 204).

ANALOG FIELD: **BASIN DAKOTA**

Figures J-23 and J-24

Location:	T23-32N, R3-14W, partly on Reservation
Formation:	Dakota
Lithology:	Sandstone
Average Depth:	6,500 feet
Porosity:	5 to 15%
Permeability:	0.1 to 0.25 md, fracture enhanced
Oil/Gas Column:	250 feet
Average Net Pay Thickness:	50 to 70 feet
Other Information:	Gas yields 1,100 Btu per CF and contains 3 to 5% carbon dioxide. Estimated ultimate recovery for the Basin Dakota Gas Field is 5 TCFG.

MANCOS FRACTURED SHALE PLAY

USGS 2208

The Mancos Fractured Shale Play Play is a confirmed, unconventional, continuous-type play. It is dependent on extensive fracturing in the organic-rich marine Mancos Shale. Most developed fields in the play are associated with anticlinal and monoclinal structures around the eastern, northern, and western margins of the San Juan Basin.

Reservoirs: Reservoirs are comprised of fractured shale and interbedded coarser clastic intervals at approximately the Tocito Lentil level.

Source rocks: The Mancos Shale contains 1-3 weight percent organic carbon and produces a sweet, low-sulfur, paraffin-base oil that ranges from 33 degrees to 43 degrees API gravity.

Timing: The upper Mancos Shale of the central part of the San Juan Basin entered the thermal zone of oil generation in the late Eocene, and of gas generation in the Oligocene.

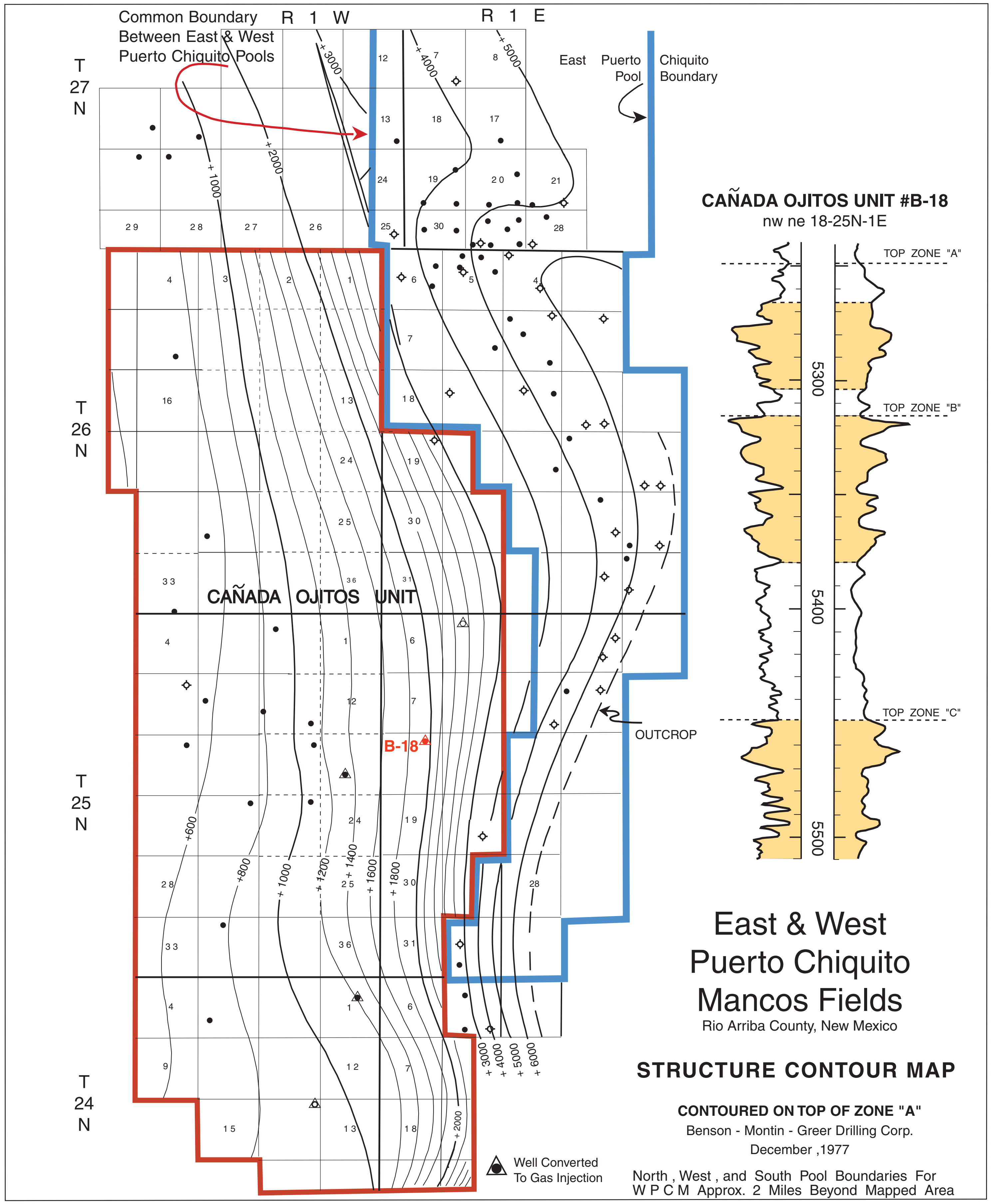
Traps: Combination traps predominate; Traps formed by fracturing of shale and by interbedded coarser clastics on structures are common.

Exploration status and resource potential: Most of the larger discoveries such as Verde and Puerto Chiquito were made prior to 1970, but directional drilling along the flanks of some of the poorly explored structures could result in renewed interest in this play.

Analog Field
PUERTO CHIQUITO MANCOS, WEST
(Figure J-25)

Location:	T25-27N, R1E and R1W, partly on Reservation
Formation:	Mancos, Niobrara equivalent section
Lithology:	Shale
Average Depth:	5,400 feet
Porosity:	Indefinite, fracture porosity
Permeability:	Unknown, transmissibility up to 6 darcy-feet
Oil/Gas Column:	250 feet
Average Net Pay Thickness:	Unknown, less than 50 feet
Other Information:	The Canada Ojitos Units lies totally within the Puerto Chiquito West Field. Originally a gravity drainage field, final stages of development will include expansion gas drive and reinjection of produced gas. Oil gravity is 39 to 40 degrees API.

Figure J-25. Puerto Chiquito Mancos East and West Fields with structure map and example electric log. Contoured on top of "A" zone (from Greer, 1978, p. 468).



CENTRAL BASIN MESAVERDE GAS PLAY

USGS 2209

The unconventional continuous-type Central Basin Mesaverde Gas Play is in sandstone buildups associated with stratigraphic rises in the Upper Cretaceous Point Lookout and Cliff House Sandstones. The major gas-producing interval in the San Juan Basin, the Upper Cretaceous Mesaverde Group, is comprised of the regressive marine Point Lookout Sandstone, the nonmarine Menefee Formation, and the transgressive marine Cliff House Sandstone. Total thickness of the interval ranges from about 500 to 2,500 ft, of which 20 - 50 percent is sandstone. The Mesaverde interval is enclosed by marine shale: the Mancos Shale is beneath the interval and the Lewis Shale above.

Reservoirs: Principal gas reservoirs productive in the Mesaverde interval are the Point Lookout and Cliff House marine sandstones. Smaller amounts of dry, nonassociated gas are produced from thin, lenticular channel sandstone reservoirs and thin coal beds of the Menefee. Much of this play is designated as tight, and reservoir quality depends mostly on the degree of fracturing. Together, the Blanco Mesaverde and Ignacio Blanco fields account for almost half of the total nonassociated gas and condensate production from the San Juan Basin. Within these two fields porosity averages about 10 percent and permeability less than 2 mD; total pay thickness is 20-200 ft. Smaller Mesaverde fields have porosities ranging from 14 to 28 percent and permeabilities from 2 to 400 Md, with 6 - 25 ft of pay thickness.

Source rocks: The carbon composition (Cl/Cl-5) of 0.99-0.79 and isotopic carbon (dl3Cl) range of -33.4 to -46.7 per mil of the nonassociated gas suggest a mixture of source rocks including coal and carbonaceous shale in the Menefee Formation (Rice, 1983).

Timing and migration: In the central part of the basin, the Mancos Shale entered the thermal zone of oil generation in the Eocene and of gas generation in the Oligocene. The Menefee Formation also entered the gas generation zone in the Oligocene. Because basin configuration was similar to that of today, updip migration would have been toward the south. Migration was impeded by hydrodynamic pressures directed toward the central basin, as well as by the deposition of authigenic swelling clays due to dewatering of Menefee coals.

Traps: Trapping mechanisms for the largest fields in the central part of the San Juan Basin are not well understood. In both the Blanco Mesaverde and Ignacio Blanco fields, hydrodynamic forces are believed to contain gas in structurally lower parts of the basin, but other factors such as cementation and swelling clays may also play a role. Production depths are most commonly from 4,000 to 5,300 ft. Updip pinchouts of marine sandstone into finer grained paludal or marine sediments account for almost all of the stratigraphic traps with a shale or coal seal.

Exploration status and resource potential: The Blanco Mesaverde field discovery well was completed in 1927, and the Ignacio Blanco Mesaverde field discovery well was completed in 1952. Areally, these two closely adjacent fields cover more than 1,000,000 acres, encompass much of the central part of the San Juan Basin, and have produced almost 7,000 BCFG and more than 30 MMB of condensate, approximately half of their estimated total recovery. Most of the recent gas discoveries range in areal size from 2,000 to 10,000 acres and have estimated total recoveries of 10 to 35 BCFG.

ANALOG FIELD
Blanco Mesaverde

Figure J-26

Location:	T25-32N, R2-13W, on Reservation
Formation:	Mesaverde, Cliff House and Point Lookout members
Lithology:	Sandstone
Average Depth:	4,500 feet
Porosity:	10 to 16%
Permeability:	Cliff House 0.5 md, Point Lookout 2.0 md
Oil/Gas Column:	400 feet
Average Net Pay Thickness:	80 to 200 feet
Other Information:	Gas carries 1,194 Btu per CF, about 1% inert (carbon dioxide and nitrogen). Associated oil ranges between 33 and 60 degrees API. Estimated field ultimate recovery 12 TCFG. In 1975 field spacing was changed to 1 well per 320 acre spacing unit.

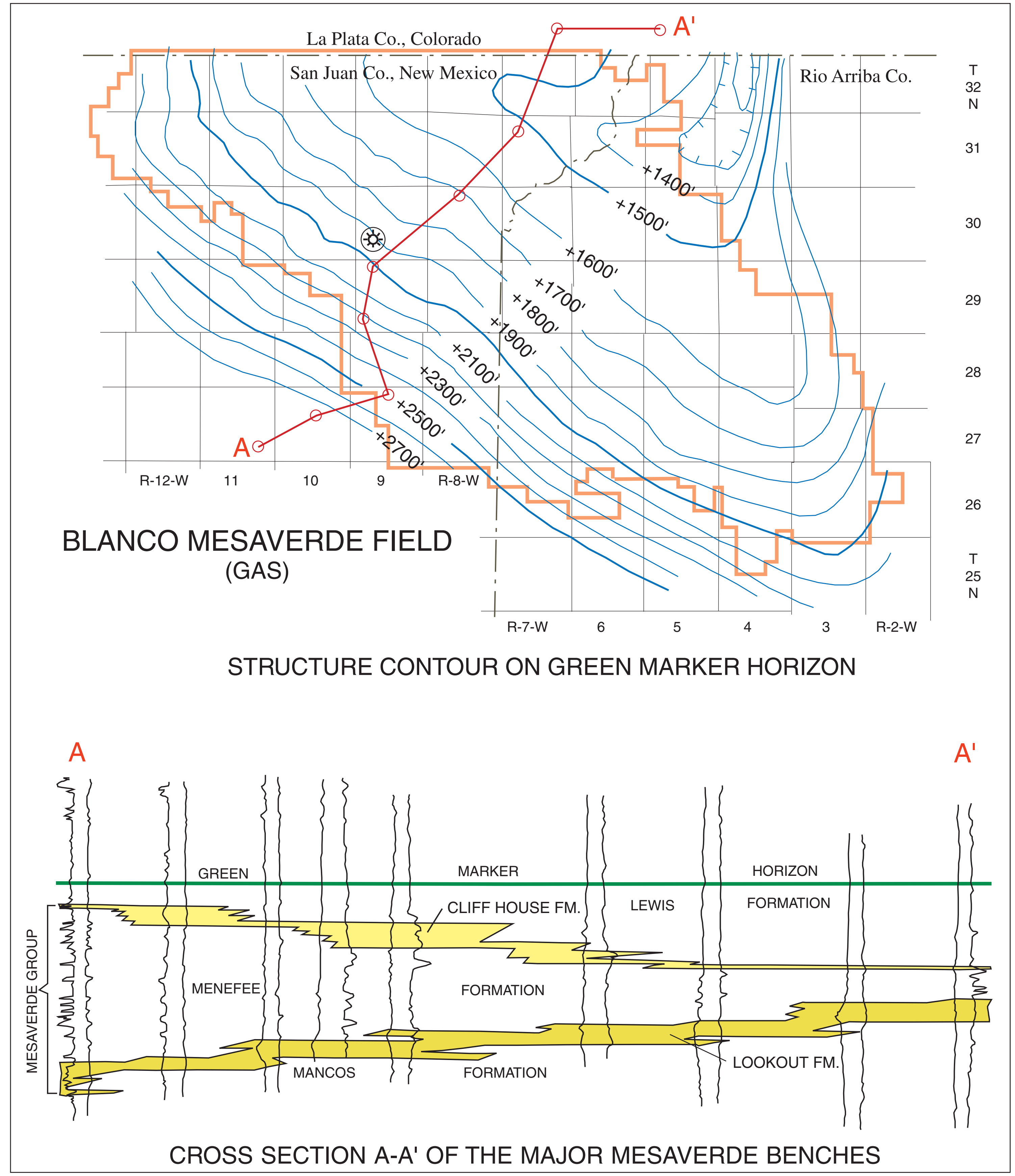


Figure J-26. Blanco Mesaverde Field structure map and cross section showing Point Lookout and Cliff House sandstones (from Pritchard, 1978, p. 222).

PICTURED CLIFFS GAS PLAY - USGS 2211

The Pictured Cliffs unconventional continuous-type play is defined primarily by gas production from stratigraphic traps in sandstone reservoirs enclosed in shale or coal at the top of the Upper Cretaceous Pictured Cliffs Sandstone and is confined to the central part of the basin. Thicker shoreline sandstones produced by stillstands, or brief reversals in the regression of the Cretaceous sea to the northeast have been the most productive. The Pictured Cliffs is the uppermost regressive marine sandstone in the San Juan Basin. It ranges in thickness from 0 to 400 ft and is conformable with both the underlying marine Lewis Shale and the overlying nonmarine Fruitland Formation.

Reservoirs: Reservoir quality is determined to a large extent by the abundance of authigenic clay. Cementing material averages 60 percent calcite, 30 percent clay, and 10 percent silica. Average porosity is about 15 percent and permeability averages 5.5 millidarcies, although many field reservoirs have permeabilities of less than 1 mD. Pay thicknesses range from 5 to 150 ft but typically are less than 40 ft. Reservoir quality improves south of the deepest parts of the basin due to secondary diagenetic effects.

Source rocks: The source of gas was probably marine shale of the underlying Lewis Shale and nonmarine shale of the Fruitland Formation. The gas is non-associated and contains very little condensate (0.006 gal/MCFG). It has a carbon composition (C1/C1-5) of 0.85-0.95 and an isotopic carbon (dl3C1) range of -43.5 to -38.5 per mil (Rice, 1983).

Timing and migration: Gas generation was probably at a maximum during the late Oligocene and the Miocene. Updip gas migration was predominantly toward the southwest because the basin configuration was similar to that of today.

Traps: Stratigraphic traps resulting from landward pinchout of nearshore and foreshore marine sandstone bodies into finer grained silty, shaly, and coaly facies of the Fruitland Formation (especially in the areas of stratigraphic rises) contain most of the hydrocarbons. Seals are formed by finer grained back-beach and paludal sediments into which marine sandstone intertongues throughout most of the central part of the basin. The Pictured Cliffs Sandstone is sealed off from any connection with other underlying Upper Cretaceous reservoirs by the Lewis Shale. The Pictured Cliffs crops out around the perimeter of the central part of the San Juan Basin and is present at depths of as much as 4,300 ft. Most production has been from depths of 1,000-3,000 ft.

Exploration status and resource potential: Gas was discovered in the play in 1927 at the Blanco and Fulcher fields of northwest New Mexico. Most Pictured Cliffs fields were discovered before 1954, and only nine relatively small fields have come into production since then. Discoveries since 1954 average about 11 BCFG estimated ultimate recovery. A large quantity of gas is held in tight sandstone reservoirs north of the currently producing areas. Stratigraphic traps and excellent source rocks are present in the deeper parts of the basin, but low permeabilities due to authigenic illite-smectite clay have thus far limited production.

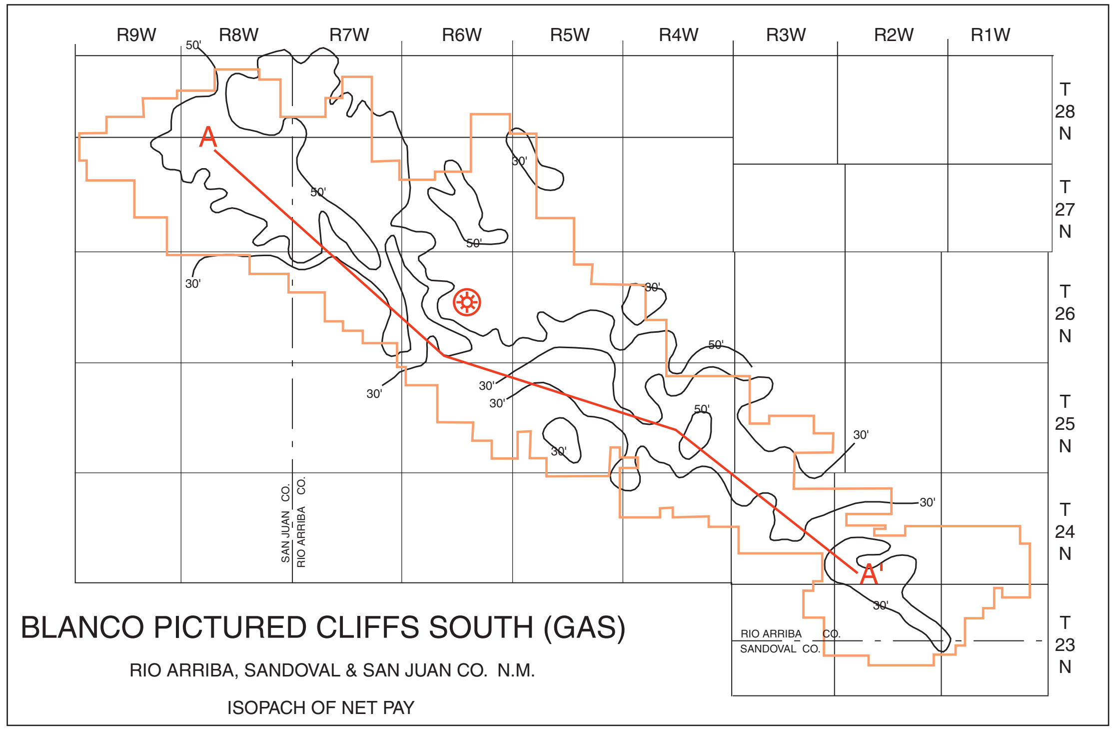


Figure J-27. Blanco Pictured Cliffs Field map with isopach of net pay (from Brown, 1978, p. 230).

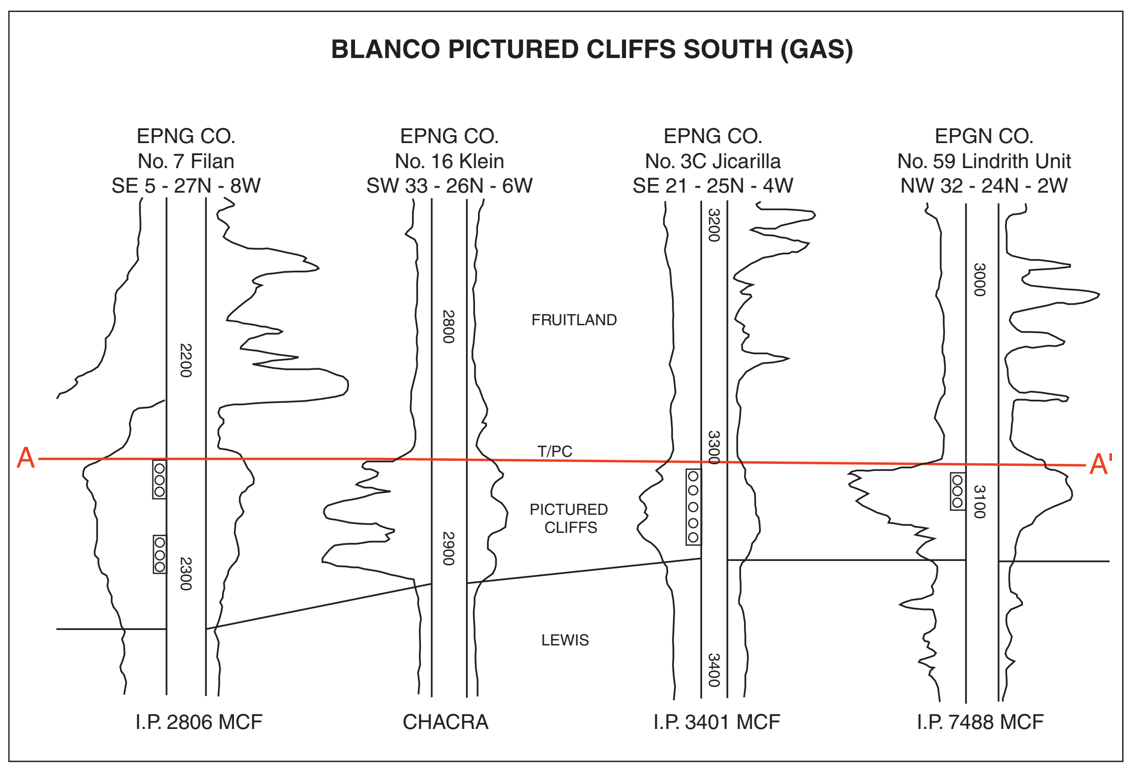


Figure J-28. Blanco pictured Cliffs Field cross section (from Brown, 1978, p. 230).

Analog Field: Blanco Pictured Cliffs, South

Figures 27, 28 and 29

Location:	T23-28N, R1-9W, partly on Reservation
Formation:	Pictured Cliffs
Lithology:	Sandstone
Average Depth:	3,000 feet
Porosity:	15%
Permeability:	0 to 5.5 mD
Oil/Gas Column:	less than 100 feet
Average Net Pay Thickness:	30 feet
Other Information:	Gas yields 1,177 BTU per CF. Estimated ultimate recovery for the field is 1.4 TCFG. Wells are on 160 acre spacing.

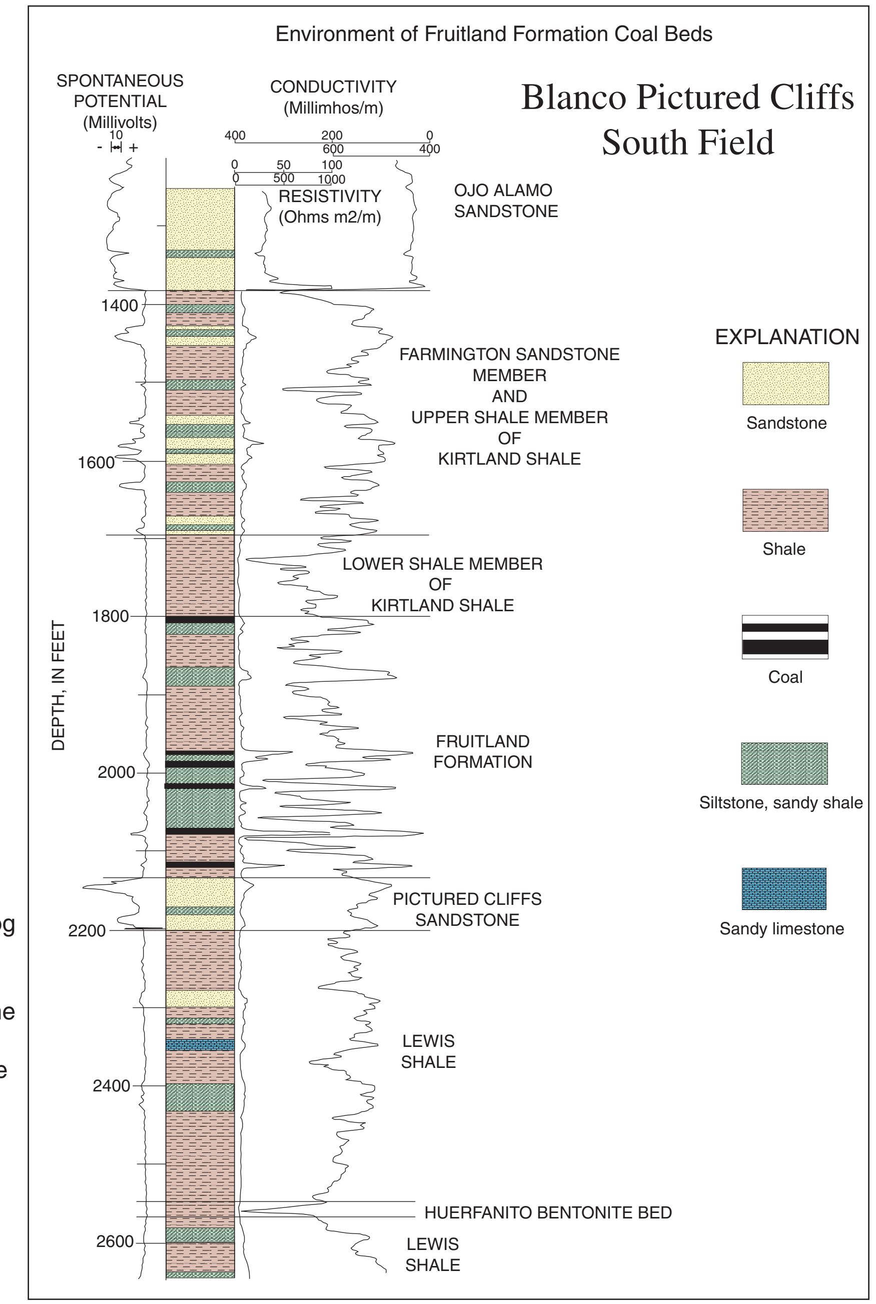


Figure J-29. Electric log and lithologic section showing relationship of Pictured Cliffs sandstone to other upper Cretaceous sandstones. Note the Huerfano Bentonite bed - see Figures J-10 and J-11 (from Fassett, 1988, p.27).